Electric Vehicle Safety Resources for Electrical Safety in Design

**IMPORTANT USER NOTE: This document was created in 2014 by the DoD Electrical Safety Working Group (ESWG)and is based on Codes and Standards in force in 2014. To use this document properly, the user must refer to the code in force at the date of use.*

Resource	Summary
Fire Protection Research Foundation report: Electrical Vehicle Charging and NFPA Electrical Safety Codes and Standards Link: http://www.nfpa.org/research/fire-protection-research-foundation/reports-and-proceedings/electrical-safety/new-technologies-and-electrical-safety/electrical-vehicle-charging-and-nfpa-electrical-safety-codes	• The National Fire Protection Association (NFPA) and the SAE International released a summary report from the co-hosted U.S. National Electric Vehicle Safety Standards Summit held in October 2011 that focused on how current codes and standards address safety and electrical infrastructure concerns related to electric vehicles. • The summary report prepared by the Fire Protection Research Foundation, an affiliate of NFPA, focused on fundamental codes and standards as they pertain to electric vehicles.
NFPA Electric Vehicle Safety Training Link: http://www.evsafetytraining.org/resources/research.aspx	• NFPA's Electric Vehicle Safety Training project is a nationwide program to help firefighters and other emergency responders prepare for the growing number of electric vehicles on the road in the United States.
ISO 6469-3: 2011 Electric Road Vehicles – Safety Specifications Part 3: Protection of Persons against Electrical Hazards Link: http://www.iso.org/iso/catalogue_detail?csnumber=45479	• Establishes that persons should be protected by a minimum insulation resistance of 100 ohms/volt in vehicles with direct current (DC) voltages greater than 60 volts but less than or equal to 1500 volts. • Specifies requirements for the protection of persons against electrical hazards on battery-powered electric vehicles (passenger cars and light commercial vehicles) when the vehicles are not connected to an external power supply. • Applicable only if the maximum working voltage of an on-board electrical circuit is lower than 1000 volts AC or 1500 volts DC or lower. • Specifies voltage classes of electric circuits, protection against electrical hazards, and protection against water effects.

IEC TS 60479-1: 2005-07
Effects of Current on Human Beings and Livestock – Part 1: General Aspects
Link: Available from ANSI by payment: http://webstore.ansi.org/RecordDetail.aspx?sku=IEC%2FTS%2060479-1%20Ed.%204.0%20b:2005&source=google&adgroup=iec-ts&gclid=CPH6897xyMQCFY-EaQod1W4AVQ
	• IEC 60479 Standard consists of four parts under the general title *Effects of current on human beings and livestock:*
	  ○ Part 1: General aspects
	  ○ Part 2: Special aspects
	  ○ Part 3: Effects of currents passing through the bodies of livestock
	  ○ Part 4: Effects of lightning strokes on human beings and livestock
	• Part 1:
	  ○ Examines the effects of electric current through the human body by development of experimental impedance values composed of resistive and capacitive components.

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	○ Proposes criterion/technical specifications for the admissible limit of touch voltage (the product of the current through the body called touch current and the body impedance) as a function of time.
SAE J2344, June 1998, revised 2010 Guidelines for Electrical Vehicle Safety Link: http://standards.sae.org/j2344_201003/ Note: The architecture, size and chemistry of the electric vehicle's high voltage source have significantly changed since 1998 when this Society of Automotive Engineers' Information Report was first issued. Refer to the most recent guideline revision.	• First attempt to formalize a list of important safety guidelines during normal operation and charging that should be considered when designing electric vehicles for use on public roadways. • Forms the basis for a later document, SAE J2578 January 2009. SAE J2344 June 1998 states that a value of greater than or equal to 500 ohms/volt can be considered electrically isolated. • A means should be provided to detect degraded electrical isolation and that electrical isolation should be monitored continuously. Although no method is given for performing either task, the groundwork was laid for future documents to expand on these concepts.
SAE J1766 April 2005, revised 2014 Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing Link: http://standards.sae.org/j1766_201401/ Note: SAE J1766, 2014 revision is a significant update to the April 2005 version.	• Voltage levels greater than 60 volts DC are defined as high voltage. • A vehicle can satisfy the electrical isolation requirements of SAE J1766 even if no hydrogen is onboard. • Passing criteria for electrical isolation are at least 100 ohms/volt for a DC high-voltage bus that is not connected to an external power source and is monitored continuously during operation. • Fuel cells are expected to maintain an electrical isolation of at least 125 ohms/volt.
ISO 23273-3 2006 Fuel Cell Road Vehicles – Safety Specifications Part 3: Protection of Persons against Electric Shock Link: http://www.iso.org/iso/catalogue_detail.htm?csnumber=41417 Note 1: ISO 23273-1:2006, Fuel cell road vehicles -- Safety specifications -- Part 1: Vehicle functional safety specifies the essential requirements for the functional safety of fuel cell (FCV) with respect to hazards to persons and the environment inside and outside of the vehicles caused by the operational characteristics of the fuel cell power system. Note 2: ISO 23273-2:2006, Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen specifies the essential requirements for fuel cell vehicles (FCV) with respect to the protection of persons and the environment inside and outside the vehicle against	• Applies only to on-board electrical circuits with working voltages between 25 V AC and 1000 V DC or 60 V DC and 1500 V DC respectively. • The isolation resistance must be at least 100 ohms/volt or 10 mA for each class B circuit. • Lists points to be taken into account if measuring electrical isolation. This list includes disconnecting some circuits, measuring all parts of the system, disconnecting cables, and leaving various piping connected for the measurements. • ISO 23273-3:2006, Fuel cell road vehicles -- Safety specifications -- Part 3, Protection of persons against electric shock specifies the essential requirements of fuel cell vehicles (FCV) for the protection of persons and the environment inside and outside the vehicles against electric shock. • The first edition of ISO 23273:2013 cancels and replaces ISO 23273-2: 2006 and specifies the essential requirements for fuel cell vehicles (FCV) with respect to the protection of persons and the environment inside and outside the vehicle against hydrogen-related hazards. Please refer to: https://www.iso.org/obp/ui/#iso:std:iso:23273:ed-1:v1:en

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hydrogen related hazards.	
FMVSS 305: Sept 11, 2007, NHTSA-2007-28517 Notice of Proposed Rulemaking (NPRM) Electric-Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection Link: http://www.gpo.gov/fdsys/pkg/FR-2007-10-09/html/E7-19735.htm	• National Highway Traffic Safety Administration, 49 CFR 571 2007 proposal to amend the electrical safety requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 305, Electric-powered vehicles: electrolyte spillage and electrical shock protection. • Requires electrical isolation as the basis for defining electrical safety and for establishing a criterion for the prevention of electrical shock. • Enhancement is required to address electrical safety of hydrogen vehicles, particularly when testing without hydrogen onboard the vehicle. • Specifies performance requirements for limitation of electrolyte spillage, retention of propulsion batteries, and electrical isolation of the chassis from the high-voltage system during the crash event. • Electrical isolation is the electrical resistance between the vehicle high-voltage source and any vehicle conductive structure. • A high-voltage source is an electrical power-generating device or an energy storage device that produced levels equal to or greater than 60 volts DC. • At least 125 ohms/volt isolation is required for DC high-voltage systems to pass the electrical isolation test after a crash. • Geared to insuring public safety with respect to EVs, HEVs, and FCVs. As such, the information in this proposed regulation is crucial to this report. • Electrical isolation is the electrical resistance between the vehicle high-voltage source and any vehicle conductive structure. • A high-voltage source is an electrical power-generating device or an energy storage device that produced levels equal to or greater than 60 volts DC. • At least 125 ohms/volt isolation is required for DC high-voltage systems to pass the electrical isolation test after a crash.
NHTSA TP-305-01: Sept 11, 2008 Laboratory Test Procedure for FMVSS 305, Electric-Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection Link: http://www.nhtsa.gov/Vehicle+Safety/Test+Procedures	• Guidelines for uniform testing data and information recording and suggestions for the use of specific equipment and procedures for contracted testing laboratories. • Uses an active onboard high-voltage power system to determine the electrical safety of the vehicle. • Written specifically to require full engagement of the test vehicle's propulsion system before the crash test. • Provides the test procedure for FMVSS 305, but does not apply directly to HFCVs without hydrogen onboard.

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	• However, does provide both pre-crash and post-crash test procedures.
SAE J2578 January 2009 Recommended Practice for General Fuel Cell Vehicle Safety Link: http://standards.sae.org/j2578_201408/	• Provides considerable pertinent information for the test procedure. • Electrical disconnects will actuate in a crash and can be used for ensuring electrical isolation. • The electrical system can be tested without fuel onboard. • Isolation tests should be conducted through a range of environmental conditions. • Isolation measurements should be conducted downstream of an enclosed isolation device and on both sides of an external isolation device. • Any onboard energy storage device can be disconnected for the test. • Fuel cell system can be shut down for the test. • All electrical circuits that are not under test or that can be damaged can be removed from the circuit. • Test voltage can be an externally applied DC voltage at least equal to the maximum open circuit voltage of the fuel cell.

Note: Department of Transportation, National Highway Traffic Safety Administration (NHTSA), 49 CFR Part 571 is applicable to passenger cars, multipurpose passenger vehicles, trucks and buses with a gross vehicle weight rating (GVWR) of 4536 kg or less that use more than 48 nominal volts of electricity as propulsion power and whose speed, attainable in 1.6 km on a paved level surface, is more than 40 km/h.[1]

[1] Federal Motor Vehicle Safety Standards; *Electric-Powered Vehicles; Electrolyte Spillage and Electrical Shock Protection*: http://www.gpo.gov/fdsys/pkg/FR-2011-07-29/html/2011-19216.htm